EVALUATION OF SELECTED VARIETIES OF WHEAT
BARLEY, AND OATS FOR RESISTANCE TO
BARLEY YELLOW DWARF VIRUS

By

LOUIS T. PALMER

B. S., Washington State University, Pullman Washington, 1960

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Plant Pathology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1965

Approved by:

Webster H. Sill

Major Professor

TABLE OF CONTENTS

INTRODUCTION

Barley yellow dwarf virus (BYDV) is a world wide and destructive disease of cereal crops according to Bruehl (1961).

The epiphytotic of BYDV in the United States in 1959 caused severe losses to oats, barley and wheat (Murphy 1959). Losses in some Kansas oat fields were estimated at 50 per cent or more by Sill et al. (1959).

Since Oswald and Houston (1951) described BYDV and especially after the epiphytotic of BYDV in 1959, considerable research has been in progress in an attempt to find resistant varieties of oats, barley and wheat (Oswald and Houston 1953, Suneson and Ramage 1957, Schaller 1958, 1961, Sill et al 1959, Endo and Brown 1963 and Smith 1964).

The purpose of this research project was to further evaluate the oat, barley and wheat varieties recommended in Kansas for resistance to BYDV and to determine, if possible, what strains of the virus are present in the state.

REVIEW OF LITERATURE

History

In April 1951, in the vicinity of Davis, California, barley turned yellow in a short period of time. By May, reports from throughout the state were received of severe stunting and yellowing of barley, the malady had been observed previously, but not in such magnitude. Many possibilities such as nutrient deficiency, soil condition, root rot, soil pH, moisture and temperature conditions were ruled out. The manner in which healthy plants were distributed throughout the fields did not indicate a soil, agronomic of field problem J. W. Oswald and B. R. Houston (1951) found a high number of aphids associated with the diseased fields. Further study with aphids in the greenhouse led them to believe the aphids were acting as vectors of a virus disease. Although wheat and oats were also infected, the term barley yellow dwarf virus (BYDV) was suggested since the disease was first observed on barley, its major host.

The vectors found by Oswald and Houston (1951) which could transmit BYDV were: Rhopalosiphum maidis (Fitch), R. prunifoliae (Fitch), Macrosiphum granarium (Kirby) and M. dirhodum (Walker).

Prior to 1951, many reports in the literature refer to a red-leaf of oats, which suggests it may have been the same disease as BYDV. Bruehl's monograph on barley yellow dwarf (1961), refers to reports on red-leaf of oats by the following workers: Thaxter 1889; Galloway and Southworth, 1890; Manns 1909; Rademacher 1929; Sprague 1936; and Barrus 1937. All but Rademacher who was from Europe, reported this disease of oats throughout the oat growing areas of the United States. Manns (1909), was the only one to report on a possible vector. He found the English grain aphid was able to transmit or carry what he believed to be a bacterium from diseased to healthy plants. Apparently

this work by Manns went unnoticed until 1951, when the virus-vector-relationship was explained.

Takeshita (1956), finally established that the red-leaf of oats was actually identical to barley yellow dwarf virus.

Host Range

Oswald and Houston (1953) reported that the host range of BYDV included many lawn, weed, pasture and range grasses. Many of the grasses are symptomless carriers while others are damaged as much as barley or oats. The virus is assured survival wherever its economic hosts are grown because of its wide host range. Bruehl (1961) summarized the known host range of BYDV and reported 95 susceptible species of plants tested under greenhouse conditions.

Vectors

Bruehl (1961) lists the following aphids as important BYDV vectors: English grain aphid _M. granarium_ now _M. avenae_ (Fabricus), apple grain aphid _R. fitchii_ (Sanderson), bird-cherry oat aphid _R. padi_ (Linnaeus), plum grain aphid _R. prunifoliae_, greenbug or spring grain aphid _Toxoptera graminum_ (Rondani) now _Schizaphis graminum_ (Rondani), corn leaf aphid _R. maidis_, rose grass aphid _M. dirhodum_, blue grass aphid _R. poae_ (Gillette).

In Kansas four vectors have been reported by Sill et al (1959) and Saksena and Sill (1964). These are _R. padi_, _S. graminum_, _R. maidis_ and _M. avenae_. The greenbug is the most frequent aphid found in Kansas on small grains and can be very damaging, even without the virus. Dody (1961) reported the greenbug to be a very efficient vector of BYDV. Saksena et al (1964) reported that four biotypes of the corn leaf aphid varied considerably in vector efficiency, but even so were important vectors of all tested isolates of the virus.

The efficiency of the vectors as reported by Bruehl (1961) varied from state to state and probably depended on the virus source of strain. Rochow (1958, 1960, 1965) has reported vector specificity among the aphids and virus strains.

Symptoms

Oswald and Houston (1953) described the symptoms of BYDV as follows:

Barley: Plants infected in the seedling stage develop symptoms 12-15 days following inoculation. The leaves start to turn yellow at the tips and the yellowing progresses downward along the margin and gradually supplants all the normal green pigmentation of the leaves (Plate V). The color is a bright golden-yellow, sometimes almost orange. In later stages the leaves die and turn brown. The symptoms usually appear in the older leaf and then in subsequent leaves. Stunting may be more severe in some barley varieties. Tillering may take place, but very little seed is produced.

Oats: Symptoms and disease development in oats is similar to barley except the color is red instead of yellow (Plate V). The tips of the leaves turn yellowish-green 15-20 days after inoculation. These blotches become red to reddish brown or purple and coalesce leaving the entire leaf tip red. The blotches continue in advance of the red discoloration from the tip downward to the base of the leaf. At advanced stages the leaf turns brown and dies. Plants become stunted as they mature. Blasting of flower parts is another symptom present in oats. This may be either a few florets or entire heads. These blasted heads or portion of heads are devoid of seed and are white in color.

Geographical Distribution and Damage

Since 1951, barley yellow dwarf virus has been reported in Canada, Mexico, and nearly every state in the United States. BYDV has also been reported in

Great Britain, New Zealand, Norway, Sweden, France, Finland, Australia, Tasmania, Israel and Czechoslovakia. The distribution is nearly world wide because of the abundance of the cereal crops grown and the presence of many of the same virus vectors. This is probably the most wide spread virus disease of the Gramineae (Bruehl 1961).

The most severe epiphytotic of BYDV was in 1959 when it was the most destructive disease affecting oats in the United States. Losses to barley and wheat were also severe. Losses in 20 states are summarized in Supplement 262 of the Plant Disease Reporter by Murphy (1959) and Monograph No 1, American Phytopathological Society by Bruehl (1961). The distribution of BYDV up to 1959 was widespread but damage was confined to certain smaller areas.

In Kansas, Sill et al (1959), reported a twenty-five per cent loss to the oat crop, two per cent loss in spring barley and some damage to winter barley and winter wheat.

Strains

Barley yellow dwarf virus has great variations indicated by the existence of strains (Bruehl 1955, 1957, 1961, Allen 1959 and Rochow 1959). Allen (1957) selected three barley varieties: Rojo, Blackhulless and Atlas 46 and one oat variety: Coast Black, to differentiate strains of BYDV.

Table 1A. Seven strain types of BYDV identified by Allen 1957.

	Reactions of Indicated Varieties			
Strain Type[1]	Blackhulless	Rojo	Atlas 46	Coast Black
Type I	+	+	+	+
Type II	+	0	+	+
Type III	+	0	0	+
Type IV	+	+	0	+
Type V	0	0	+	+
Type VI	0	0	+	0
Type VII	0	0	0	-

1/ Strain type coded according to presence (+) or absence (0) of discoloration.

Some strains of BYDV were determined by vector relationships as first reported by Toko and Bruehl (1957) and later denied (Toko and Bruehl (1959). Rochow (1959, 1960, 1965) found vector specificity which appeared to be useful in strain identification among the English grain and apple grain aphids.

In Kansas, at least two strains, based upon host reaction, were found by Saksena in collections made by Dody, Saksena and Sill (unpublished data).

The significance of strains and isolates identified on grass hosts is explained by Bruehl (1961). Strains of varying severity based on reaction of small grains will affect breeding programs for the control of BYDV (Bruehl and Toko 1955, Takeshita 1956, and Rasmusson 1959).

Control

Insecticides: Pizarro and Arny (1958), Caldwell (1959), Dickerson (1960), Jedlinski (1961), and Paterson (1963) evaluated insecticides such as Systox (mixture of O;O-diethyl O-2-(ethylthio) ethyl phosphorothioate) and Dimethoate (O;O-diethyl S (N-methylcarbamoyl-methyl) phosphorodithioate) for control of BYDV vectors. These insecticides will control the vectors, but are not presently recommended because of the cost, number of applications necessary for control and the fact that viruliferous vectors often cannot be killed before they feed and transmit the virus.

Resistant Varieties

Barley. Oswald and Houston (1953) found a high degree of tolerance in barley varieties CI nos 1227, 1237, 2376, and Abate (CI No 3920-1). Suneson and Ramage (1957) reported on the importance of tolerance in commercial varieties of barley in a study of comparative yields. Rojo and Velvon 11 yielded 40 bu/A., Hannchen and Kindred 28 bu/A., Club Mariout and Compana 16 bu/A., and

Nepal and Bonneville only 4 bu/A. in California field trials.

Schaller (1958, 1960, 1961) screened 6,728 barleys of the United States Department of Agriculture collections and found the most resistant barleys were of Ethiopian origin. Schaller listed CI nos. 3208-2, 3208-4, 3906-1, 3906-4, 3908-1 and 3926-3 as possessing the highest resistance yet found in California.

In Wisconsin, Arny (1958) reported the variety Kindred appeared to be more tolerant to BYDV than Montcalm and Wisconsin Barbless. Arny also reported several CI nos. from Ethiopia, England, Egypt, Poland and France that had some tolerance to BYDV.

According to Damsteegt et al. (1961), breeding for resistance to BYDV in barley appears to be profitable and should be continued.

Oats. Sill et al. (1959) observed Kanota had some tolerance to BYDV in Kansas fields. Kanota resistance has also been reported in California by Oswald and Houston (1953), and Suneson and Ramage (1957) and in Washington by Bruehl and Damsteegt (1959).

Endo and Brown (1957, 1963) tested over 4,000 varieties of oats in the field in Illinois, using the apple grain aphid as a vector for selected strains of the virus. The highest resistance was found in Avena strigosa selections. Avena satira selections which had some resistance were Albion (CI 729), Fulghum (CI 1915), and CI 4918.

Shands and Cruger (1959) in Wisconsin noted some tolerance to BYDV among the commercial oat varieties: Ajax, Beedee, Fundy, Garry, Newton, and CI nos. 7372 and 7107.

Putnam is reported to have resistance to BYDV in the midwest (Browning et al. 1959, Caldwell 1959, Jedlinski and Brown 1959, Sechler et al. 1959, and Sill et al 1959). Browning et al. (1959) also listed Newton as resistant.

Wheat. Oswald and Houston (1953) listed Sonora 37 as the most tolerant to BYDV of several varieties of wheat tested. Bruehl (1961) reported that in the screening of over 3,000 winter wheats, Sun and Red Russian (CI4509) were very tolerant. Others of promise were CI Nos. 11230, 11234, 11236 and PI Nos. 108980 and 108981.

Smith (1964) in New Zealand tested 4,000 wheat varieties of the United States Department of Agriculture, 400 varieties of the Crop Research Division and 200 varieties from Ethiopia and found few varieties which had any resistance to BYDV. However the variety 705.01 had a high degree of tolerance and Cross 7-35, Jade, Aotea and Gabo were moderately resistant to barley yellow dwarf virus.

As a result of this testing and evaluating, varieties of oats, barley and wheat are now being released which are known to have some resistance to at least certain strains of BYDV. Since aphids and infected hosts are present each year and disease development depends on the environment, the best control of BYDV appears to lie in the development of varietal resistance to the virus in each region where the disease is of importance.

MATERIALS AND METHODS

Research Area

Greenhouse. Virus isolates were maintained in a section of the mosaic greenhouse at Kansas State University. The section was heated with forced air during the winter and cooled with exhaust fans and an evaporative cooling system in the summer. Temperatures in the winter averaged 70°F during the day and 60°F at night. Summer temperatures averaged about 85°F during the day and 70°F at night. Shading compound was applied in the summer to reduce the light intensity. Humidity varied inversely with the temperature and averaged 40 per

cent or more. Fumigation with a plant-fume generator containing nine per cent parathion as the active ingredient was used at weekly intervals. Fertilizer was applied to plants as necessary. Steam sterilized soil in six inch pots was used in all investigations. The soil consisted of two parts loam, one part sand and one part peat moss.

Field. Plots were located on several farms of the Kansas State University Experiment Station at Manhattan, Kansas. Most of the soil was a heavy, silt loam, river bottom soil. Fertilizer was applied in the form of ammonium nitrate (33-0-0) at 110 pounds per acre. Sprinkler irrigation was used when necessary.

Virus Source. Twenty three virus isolates were obtained from K. N. Saksena (former Graduate Research Assistant at Kansas State University), who made the collections with Sill and Dody. Saksena and Sill (1964 unpublished) identified two strains of BYDV from these collections. Strain one was chosen for these experiments as it was found most frequently in the Kansas collections. This strain corresponded to the type II strain identified by Allen (1957).

The virus isolates were maintained on Kanota oats and transferred every eight weeks to seedling plants. Transfers were made using the cut leaf method as described by Rochow (1958), and Watson and Mulligan (1960). R. padi a very efficient vector as reported by Saksena and Sill (1964) and was used for all the routine virus transfers (Plate I).

Aphid Colonies. Four aphid species obtained from Saksena were maintained throughout the study. These were: R. padi (Plate I), M. avenae (Plate II), R. maidis (Plate III), and S. graminum (Plate IV), (Palmer 1952, Russell 1963). The aphid species were identified by Louise M. Russell of the United States Department of Agriculture Insect Identification Laboratory, Washington, D. C.

Reno and Blackhulless barley thickly sown in six inch pots was used to maintain the aphid colonies. A cellulose nitrate cage sealed at the top with nylon taffeta, as described by Bruehl (1961), was used to confine the aphids on the plants. The aphids were transferred to new plants as they became over-populated by either removing a leaf containing aphids or using a fine camel's hair brush.

Virus free aphids were obtained by placing adult aphids on filter paper in a petri dish and removing the nymphs as they hatched as suggested by Oswald and Houston (1953). The colonies were frequently checked for contamination by removing a few aphids and placing them on healthy Kanota oat seedlings. Also the barley used for the colonies was susceptible to BYDV and acted as an indicator of infected colonies.

The colonies were maintained in a growth chamber held at 65°F with a minimum light intensity of about 200 foot candles, a day length of 14 hours and a humidity of approximately 40 per cent.

All colonies were replaced yearly by field collections as suggested by Painter (1951). The reason for this was that the insects become adapted to an ideal environmental condition and may not perform as they do in nature.

Virus Inoculation Technique

Greenhouse. Leaves from virus infected plants were cut, washed, and placed in petri dishes containing moist filter paper (Plate I). Aphids were removed from the stock colonies by tickling the aphid with a brush to encourage movement and withdrawal of the stylet from the leaf and gently picking up the aphid. They were then placed on the cut leaves. The petri dishes were moved to a growth chamber for a two or three day acquisition feeding period. The supposedly viruliferous aphids were then transferred to individual healthy Kanota oat seedlings. A plastic test tube 1" x 8" with holes cut in the tube

PLATE I

The "cut leaf" virus acquisition technique using R. padi aphids.


2A1850-1

PLATE II

M. avenae adult parthenogenetic females. (Photograph courtesy of R. H. Painter).

PLATE III

R. *maidis* showing differences in size of alate ovaviviparíae adults. (Photograph courtesy of R. H. Painter).

PLATE IV

S. graminum colony on a wheat leaf. Note the light colored spots due to the toxic substance produced by the aphids while feeding. (Photograph courtesy of R. H. Painter).

and covered with nylon taffeta was placed over the aphid and oat seedling and thrust into the soil. The aphids were left for the two or three day inoculation period before killing them with nicotine sulfate spray (Black Leaf 40).

Field. Flats seeded with Reno barley were inoculated with viruliferous aphids from a known virus source and a large population was built up. The flats were kept in the hallways of the greenhouse and in the window sills of a laboratory. It took about two months from time of planting and inoculation to build up large populations.

One flat was sufficient to inoculate about eight rows of grain ten feet long. Leaves containing the aphids were cut from the flats and placed beside the crown of the plants to be inoculated. As the cut leaves dried the aphids moved to the growing plants. Although it took only one aphid per plant for virus inoculation, the release of several in the vicinity assured that one aphid would feed on the desired plants. Movement of aphids from plant to plant was erratic as observed by Orlob and Medler (1961). Aphid mortality was high due to predators and extreme climatic conditions such as rain and hail.

After a five day inoculation period the plots were sprayed with systox or malathion. The controls were sprayed before inoculation. All plots were then sprayed at weekly intervals until the grain began to mature.

The center two rows of the four row block of each replication were inoculated. The two outside rows acted as a border to prevent spread of the aphids.

Eight feet of the ten foot long rows which were inoculated were harvested and in some blocks because of poor stands and winter killing during the severe winter of 1965 it was necessary to compare individual healthy control and infected plants.

Varieties Tested

The following varieties were selected upon recommendation of E. G. Heyne, Agronomist, Kansas State University, Manhattan, Kansas.

WHEAT

Bison, CI 12518
Comanche, CI 11773
Concho, CI 12517
Kaw, CI 12871
Ottawa, CI 12804
Pawnee, CI 11669
Ponca, CI 12128
Quivira hybrid, CI 13285
RedChief, CI 12109
Scout, CI 13546
Triumph, CI 12132
Wichita, CI 11952

SPRING BARLEY

Beecher, CI 6566
Otis, CI 7557

WINTER BARLEY

Chase, CI 9581
Dicktoo, CI 5529
Hudson, CI 8067
Will, CI 11652
Meimi, CI 5136
Mo-B 475, CI 9168
Reno, CI 6561

OATS

Andrew, CI 4170
Kanota, CI 839
Minhafer, CI 6913
Mo-0-205, CI 4988
Neal, CI 7440
Newton, 66 CI 6642
Putnam, CI 6927
Tonka, CI 7192

EXPERIMENTAL RESULTS

Spring Barley and Oats, 1964, 1965

Spring oats and barley seeded March 5, 1964 were damaged by a late March freeze while in the seedling stage. Hot dry weather in June further reduced yields. The oats could be compared only on an individual plant basis and not on the amount of seed produced per replication as planned.

Four replications of oats and five replications of barley were inoculated with viruliferous R. padi aphids on March 9, 1964. The plots were sprayed with Malathion May 14. Symptoms were apparent in all replications by May 23. Control oat plots had a visible infection of zero to eight per cent, while control barley

plots were infected seven to thirteen per cent. The inoculated oat plots had an infection of 58 to 100 per cent and barley was infected 93 to 100 per cent.

Plant height was measured June 18. (See Table 1, 3 and 5). Some stunting was observed in the varieties with the exception of Kanota where there was no stunting in 1964.

Kanota oats, Beecher and Otis barley were harvested on July 3, and the other varieties on July 9. Yield date are summarized in Table 2, 4 and 6. The controls had a higher yield per plant than the inoculated plots.

The eight varieties of oats tested in 1965 were seeded April 8. Spring barley, Beecher and Otis were also seeded at the same time. Fifteen randomized replications of each variety were planted. Ten replications were BYDV plots and five were control plots.

The plots were inoculated with viruliferous R. padi aphids on May 8, 1965. The plots were sprayed May 15. Control plots were sprayed before inoculation and afterwards, but infection in the controls was still a higher percentage.

Symptoms were apparent in all replications by May 30. Symptom readings on oats were taken June 22, and the per cent infection ranged from 76 per cent in Kanota to 88 per cent in Tonka. The controls ranged from 13 per cent in Newton to 36 per cent in Tonka. No attempt was made to take symptom readings in the barley in 1965 due to the high per cent of infection in both control and inoculated plots and the presence of leaf rust.

Plant height was measured on June 23. There was less stunting in 1965 than in 1964. See Tables 3 and 5 for a summary of the results.

The spring barley was harvested July 5, 1965 and the oats on July 7. Yield data are summarized in Table 6 for the oats. Yields of spring barley showed only slight difference in Otis and Beecher. The ten replications of inoculated Beecher Plots had an average per plant yield of 10.51 grams per

plant and the five replications of controls averaged 10.17 grams per plant. Otis BYDV plots had an average yield of 10.87 grams per plant and the controls 10.89 grams per plant. This difference does not mean the varieties are resistant to the virus since the 1964 yield data showed a significant difference. The reason for the small 1965 difference probably was due to the very favorable environment and a high per cent infection in the controls. In 1964 the per cent yield reduction was 73 in Otis and 83 in Beecher.

Based upon 1964 and 1965 yield data the eight oat varieties are grouped into four classes of resistance (Table 8). Allen (1957) used a similar classification but did not base it on yield, only on stunting and discoloration. The four classes used were: Resistant, less than ten per cent yield loss, Tolerant, ten to twenty-five per cent, Susceptible, twenty-five to fifty per cent and Very Susceptible, more than fifty per cent yield reduction.

Kanota survived the hard freeze in March 1964 better than any other variety of oats. Some loose smut was observed in the barley in 1964 and also stem rust was severe in both barley and oats in 1964 and 1965. Crown rust was severe in the oats in 1965. These other diseases were just as severe in the control as in the inoculated blocks.

TABLE 1 SPRING OATS

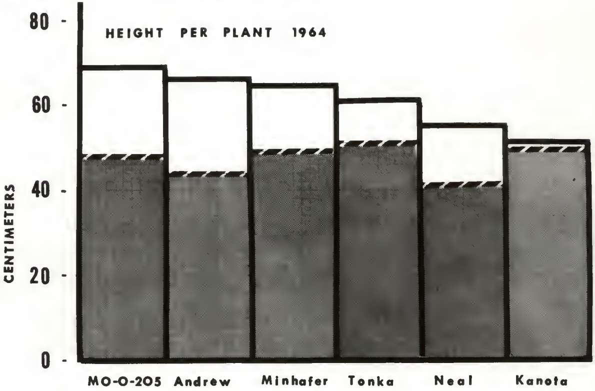


TABLE 2 SPRING OATS

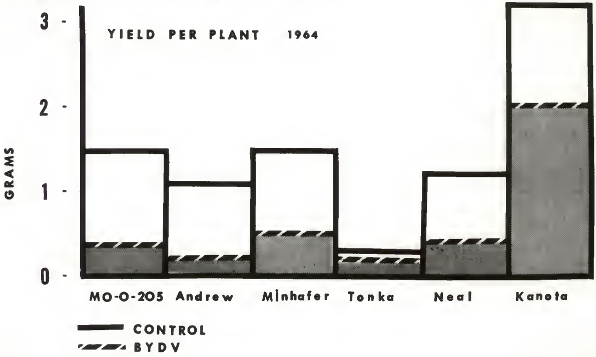


TABLE 3 Spring Barley

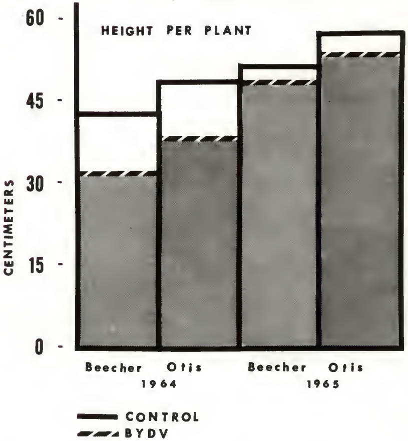


TABLE 4 Spring Barley

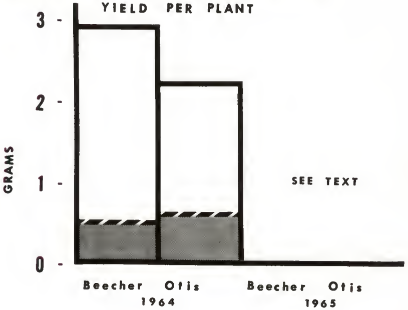


TABLE 5

Effect of BYDV on Plant Height
Spring Oats 1965

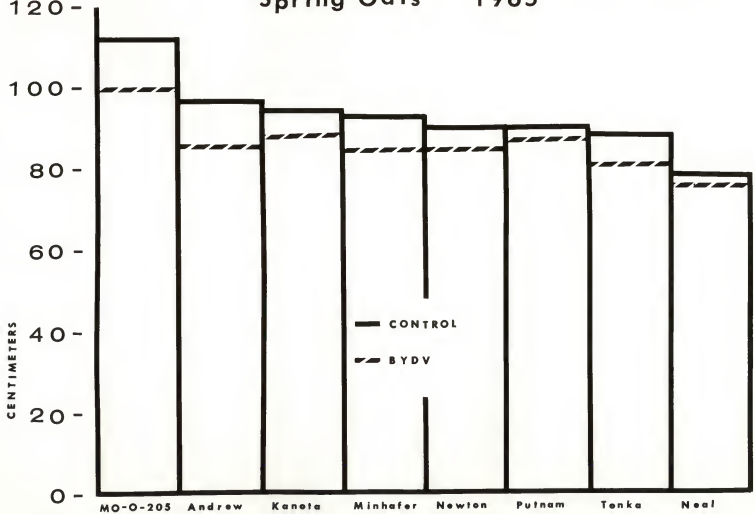


Table 6. Effect of BYDV on spring oats, 1965.

Variety	a/Plot	b/Total Yield in grams	Grams/ Plant	Total Number of Plants	Per cent Yield Reduction
Newton	C	1466	9.1	160	-
	I	2814	9.3	301	c/+2
Minhafer	C	980	11.1	88	-
	I	2022	10.9	185	2
Tonka	C	1120	10.8	103	-
	I	1841	9.1	202	16
Andrew	C	1832	15.5	118	-
	I	2494	12.4	201	20
Mo-0-205	C	1316	13.8	95	-
	I	2084	10.9	190	22
Kanota	C	1594	15.9	100	-
	I	2982	11.4	260	29
Putnam	C	2174	18.9	115	-
	I	2734	13.4	203	30
Neal	C	1970	14.7	134	-
	I	3074	10.0	307	32

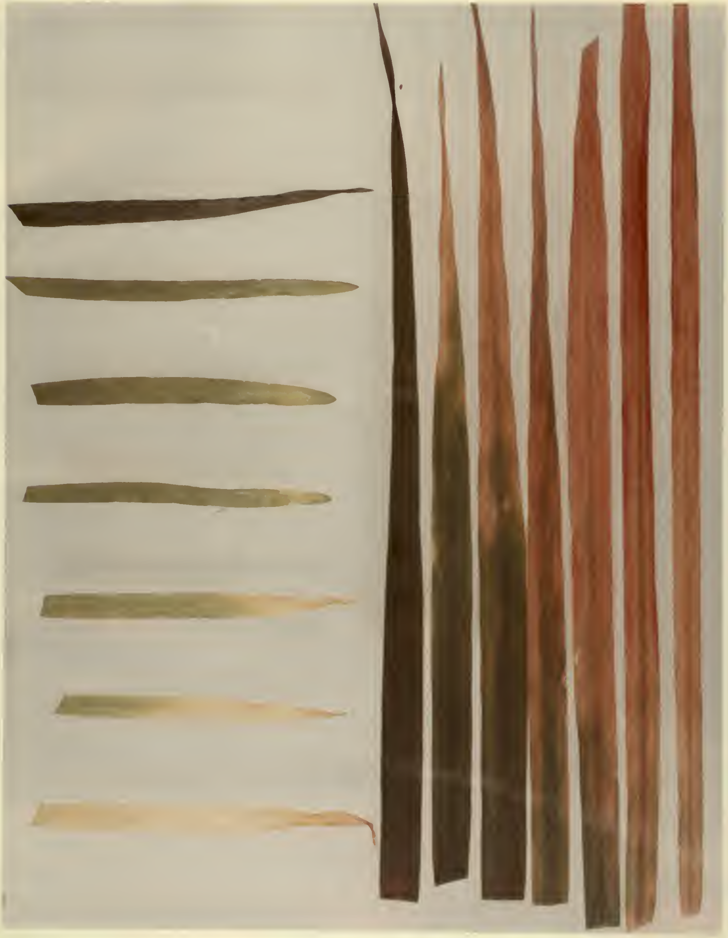
a/ Plot C = Control I = Inoculated BYDV
b/ Total yield in grams, 10 replications in inoculated and 5 replications in control. Eight feet of the two center rows were harvested.
c/ In this case no reduction in yield in inoculated plots, but rather an increase.

Table 7. Classification of spring oat varieties based on per cent yield reduction for 1964 and 1965.

Variety	Classification	Per cent yield reduction 1964	1965	Average
Newton	Resistant	Not tested	+2	+2
Tonka	Tolerant	34	16	25
Putnam	Susceptible	Not tested	30	30
Kanota	Susceptible	38	29	33
Minhafer	Susceptible	67	2	34
Mo-0-205	Susceptible	74	22	48
Neal	Susceptible	67	32	49
Andrew	Very Susceptible	82	20	51

PLATE 5.

Symptoms of BYDV on Reno barley (left) and Kanota oat leaves (right). Healthy leaves, top left of barley and far left of oats.



Winter Wheat

Twelve varieties were sown with a hand planter (Planet Jr.) using a hole opening of 20 size No. 5459. The wheat was planted September 27, 1964. Irrigation was required in the fall since there was so little moisture.

Four replications of wheat were inoculated October 29, 1964 with viruliferous _R. padi_ aphids. The plots were sprayed five days later with systox. Before inoculation, the controls were sprayed. No further spraying was done in the fall.

Three replications of wheat were inoculated April 15 and three replications inoculated on April 19. _R. padi_ was used as the vector on five replications and _S. graminum_ for the other replication. The plots were sprayed as described above and spraying was continued about every ten days until the wheat began to mature.

Wheat inoculated in the seedling stage did not show symptoms until growth began in the spring. Then the yellowing of the leaves progressed from the tip inward in the same manner as described for barley and oats. (Plate VI). Stunting was severe in some varieties, yields were reduced and winter killing was higher in infected plots. Early spring inoculation produced the same symptoms with less stunting and yield reduction. In both cases the entire plant became yellowed. The first symptoms were observed April 14, 1965. Late infection in the jointing or tillering stage produced only a yellow flag leaf and at maturity infected heads became black (Plate VII). Smith and Wright (1964) also reported these symptoms. On May 8, 1965 the spring inoculated plots showed the same bright yellow symptoms as observed in the fall inoculated plots. There was some difference in the degree of coloring among the twelve varieties, but all of them did show symptoms.

Winter killing was evident in the fall inoculated plots as summarized in

Table 8. Ponca was the most severely damaged. Only 75 per cent survived in the BYDV plots while 98 per cent survived in the control. The least winter killed was Ottawa with only one per cent difference between the BYDV plots and the controls. All varieties were damaged by the winter and the BYDV plots always had fewer surviving plants than the controls.

None of the winter wheats exhibited good resistance to the virus with fall inoculation. Triumph had the least amount of yield reduction, 25 per cent, and Bison had the highest with 60 per cent. This does not take into consideration the winter killing percentage. Table 10 summarizes the yield data and the per cent yield reduction for both fall and spring inoculations.

The spring inoculations proved that the wheat varieties may have either some mature plant resistance or else inoculation was too late to be effective. Inoculated Triumph and Ponca actually yielded more than the controls. Comanche had only a five per cent yield reduction in spring inoculation but Kaw had a 35 per cent reduction.

Based on the one year's yield data Triumph seems to have the most resistance to the virus if winter killing data are excluded. If winter killing is included, then Concho rates the best.

Stunting, as summarized in Table 9, shows that the virus does cause stunting in wheat and the fall inoculation plots were stunted more than the spring inoculation or the controls. Triumph was not stunted in the spring inoculation plots. The stunting apparently is not of any great significance as far as resistance to the virus is concerned.

The twelve varieties are classified in Table 11 by averaging the yield reduction of fall and spring inoculations and the difference between the per cent survival and controls. The same classification is used for oats.

See Appendix for statistical analysis.

Table 8. BYDV per cent survival winter wheat 1965.

Variety	Fall Inoculation [a/]	Control
Bison	84	96
CI 13285	89	100
Comanche	89	94
Concho	92	100
Kaw	87	93
Ottawa	95	96
Pawnee	81	97
Ponca	75	98
RedChief	92	97
Scout	89	96
Triumph	74	89
Wichita	85	95

[a/] Four replications in the fall inoculation and three replications in the control were counted. Plants were counted in the center two rows of each four row block eight feet long.

TABLE 9

Effect of BYDV on Plant Height

Winter Wheat 1965

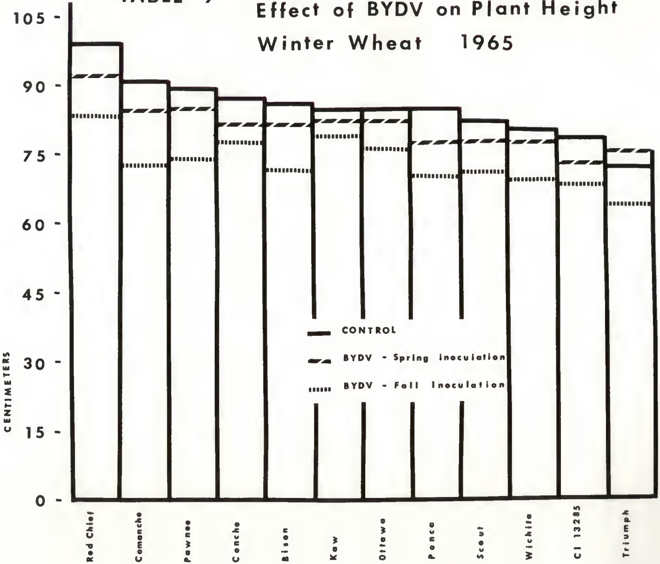


Table 10. Comparison of the effect of both fall and spring BYDV inoculations on the yield of winter wheat.

Variety	Plot	a/ Total Yield per 16 foot row all replications grams	Average yield per plant in grams	No. of Plants	Per cent Yield Reduction
Triumph	C	1537	11.91	129	c/ -
	S	1523	b/ 13.35	114	+12
	F	504	8.84	57	26
Concho	C	2482	19.85	125	-
	S	2374	18.54	128	7
	F	1088	12.80	85	36
Ponca	C	1808	14.34	126	-
	S	1782	b/ 15.10	118	+5
	F	544	8.11	67	44
Comanche	C	2418	17.77	136	-
	S	2044	17.03	120	5
	F	859	9.76	88	46
RedChief	C	2036	16.41	124	-
	S	1832	13.08	140	21
	F	860	8.95	96	46
Scout	C	2288	20.42	112	-
	S	2110	17.43	121	15
	F	770	10.54	73	49
Ottawa	C	2232	15.50	144	-
	S	2116	11.13	190	29
	F	842	7.45	113	52
CI 13285	C	2620	18.06	145	-
	S	2294	16.26	141	10
	F	903	9.21	98	50

Table 10 (cont.). Comparison of the effect of both fall and spring BYDV inoculations on the yield of winter wheat.

Variety	Plot	[a]/ Total Yield per 16 foot row all replications grams	Average yield per plant in grams	No. of Plants	Per cent Yield Reduction
Kaw	C	2112	19.55	108	-
	S	1584	12.77	124	35
	F	1005	11.16	90	43
Wichita	C	2282	19.50	117	-
	S	1974	15.42	128	21
	F	650	9.55	68	52
Pawnee	C	2392	16.84	142	-
	S	1878	12.86	146	24
	F	716	9.29	77	45
Bison	C	2120	23.04	92	-
	S	1936	16.13	120	30
	F	548	9.44	58	60

a/ C = Control 5 replications
S - Spring inoculation 6 replications
F - Fall inoculation 4 replications

b/ Triumph and Ponca had a higher yield in the spring inoculation plots than the controls.

c/ The per cent yield reduction is based on the yield of the control plots.

Table 11. Classification of wheat varieties based on the average per cent yield reduction of fall and spring inoculations and per cent difference between control and winter survival of fall inoculations.

Variety	Class	a/Total Per cent Yield Reduction	Per Cent Winter Survival		
			Fall Inoculation	Control	Difference
Triumph	Tolerant	13	74	89	15
Concho	Susceptible	43	92	100	8
Ponca	Susceptible	39	75	98	23
Comanche	Very Susceptible	51	89	94	5
RedChief	Very Susceptible	67	92	97	5
Scout	Very Susceptible	64	89	96	7
Ottawa	Very Susceptible	81	95	96	1
CI 13285	Very Susceptible	60	89	100	11
Kaw	Very Susceptible	78	87	93	6
Wichita	Very Susceptible	73	85	95	10
Pawnee	Very Susceptible	68	81	97	16
Bison	Very Susceptible	90	84	96	12

a/ Total per cent yield reduction is obtained by averaging together the spring and fall per cent yield reductions.

Table 12. Effects of fall inoculation of BYDV with four aphid species on Bison wheat grown in drill strips. 1964-1965.

Aphid Species	Total Yield Per Eight Foot Row Grams	Yield Per Plant Grams	No. of Plants	Per cent Yield Reduction	Average Plant Height Centi-Meters
Apple Grain	15	1.50	10	90	47
Greenbug	103	10.30	10	17	78
Corn Leaf	95	9.50	10	33	70
English Grain	55	5.50	10	61	79
Control	140	14.00	10	--	85

Table 13. Effects of spring inoculation of BYDV with four aphid species on Ottawa wheat grown in drill strips. 1963-1964.

Aphid Species	Total Yield Per Eight Foot Row Grams	Yield Per Plant Grams	No. of Plants	Per Cent Yield Re-duction	Average Plant Height Centi-meters
Apple Grain	185	2.80	66	36	94
Greenbug a/	369	4.98	74	+15	85
Corn Leaf	223	3.59	62	17	95
English Grain	230	4.18	55	4	92
Control	307	4.32	71	--	96

a/ The greenbug inoculated plots did not show any yield reduction but had a higher yield than the control.

Table 14. Effects of spring inoculation of BYDV with four aphid species on Ottawa wheat grown in drill strips. 1964-1965.

Aphid Species	Total Yield Per Eight Foot Row Grams	Yield Per Plant Grams	No. of Plants	Per Cent Yield Reduction	Average Plant Height Centimeters
Apple Grain	114	9.50	12	21	68
Greenbug	144	12.00	12	None	77
Corn Leaf	135	11.25	12	7	73
English Grain a/	152	12.66	12	+5	71
Control	156	12.00	13	-	74

a/ The English grain aphid inoculated plots did not show any yield reduction but had a higher yield than the control.

Tables 12, 13 and 14 show that the apple grain aphid is the most efficient vector in the field trials conducted both in the spring and fall inoculated plots. The yield reductions and stunting using this aphid were consistently greater. Bruehl (1961 and Saksena and Sill (1964) also reported the efficiency of the apple grain aphid to be higher than the other aphid species tested. Stunting did not seem to be severe in the spring but it was in the fall inoculated plots with apple grain aphids. Also the yield reduction was more severe in the fall than the spring.

PLATE VI

Symptoms of BYDV on wheat leaves. Leaf on the right is from healthy control plant.

PLATE VII

Blackened heads from a BYDV infected wheat plant. Variety shown is RedChief. The healthy heads are on the left.


D1947-1

Winter Barley

Seven varieties were sown in fifteen replications on September 25, 1964.

Five replications were inoculated with viruliferous R. padi aphids on October 24. Five replications were inoculated on April 15, 1965. Five were left as controls. Spraying was carried out as previously described for wheat.

The winter at Manhattan was very severe and survival of some winter barley varieties was poor even in the controls. Harvesting had to be on an individual plant basis.

Winter killing was more severe in the fall inoculated plots than in the controls or spring inoculated plots. Plant counts were made of all four rows in each replication. These are summarized in Table 15. The survival of Hudson was so poor that the two per cent in the controls was not considered reliable. Dicktoo and Chase had 65 and 64 per cent survival respectively in the fall plots while the controls were 90 and 82 per cent. The other varieties did not survive well and, therefore, the results are not conclusive.

The barley was harvested July 4, 1965. Yield and plant height of five varieties are summarized in Tables 16 and 17.

B-475 did not have any decrease in plant height nor in yield in the spring inoculated plots. Chase had the same yield in controls as in spring inoculation. Meimi out yielded the controls in spring inoculation. Hudson had an average yield of 5.63 grams per plant in the controls and 11.64 grams per plant in spring inoculation, but there was no grain produced in the fall inoculation plots.

Height in spring inoculation plots of Hudson was 53 centimeters as compared to 46 centimeters in the controls, but there were only 11 plants in the controls and 34 in the inoculated plots.

Table 15. Per cent survival of winter barley varieties inoculated with BYDV as compared to controls, 1964-1965.

Variety	Fall a/Inoculation Per cent	Spring Inoculation Per cent	Control Per cent
B-475	6	34	26
Chase	64	79	82
Dicktoo	65	95	90
Hudson	0	8	2
Meimi	5	21	41
Reno	5	20	12
Will	16	42	27

a/ Five replications per inoculation. All plants in four rows each ten feet long were counted in each replication.

Reno had an average yield of 21.23 grams per plant for the controls, 20.20 for spring inoculations, and 22.00 for fall inoculation plots. The plant height of Reno was 55 centimeters in the controls, 57 in spring inoculation, and 63 in fall inoculation plots. The number of plants was only 46 in controls, 67 in spring inoculation and one in fall inoculation plots. This is the total of all surviving plants.

Because of the low number of plants surviving in Hudson and Reno, the yield and plant height data are not reliable without further testing.

All of the barley varieties showed good BYDV symptoms, but the classification could not be made without more testing. From a general observation by the author, it does not appear that any of the varieties possess any high degree of resistance.

TABLE 16 Winter Barley
Yield Per Plant

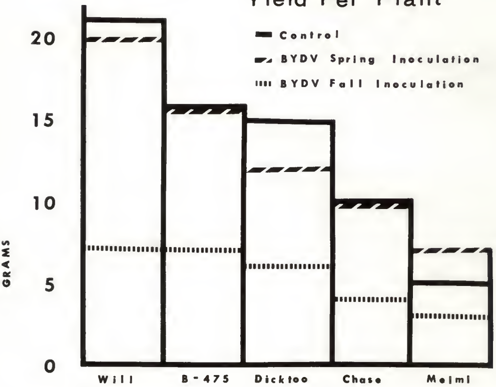
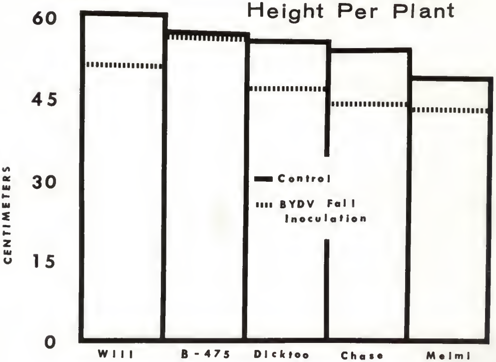


TABLE 17 Winter Barley
Height Per Plant



DISCUSSION AND SUMMARY

The studies of BYDV on oats, barley and wheat indicate that the virus has the potential to be destructive in all three hosts. None of the varieties exhibited a high degree of resistance although some tolerance was observed.

The virus effect depends greatly upon the environment. When the season was dry as in 1964, the spring barley and oats were severely damaged. In 1965 the spring was cool and moist, ideal for growth, and the plants were able to grow well in spite of the virus. However, some stunting and yield reduction was still observed.

Winter wheat was damaged much more by fall infection than by early or late spring infection. All varieties of wheat tested exhibited leaf symptoms, stunting and some yield reduction.

BYDV will probably not become a serious disease of wheat in Kansas for two reasons: first, late planting of wheat reduces the chance of large aphid vector populations in the fall; and, second, aphid populations in the spring usually appear too late after plants have grown beyond the susceptible stage. However, Kansas could serve as a source of barley yellow dwarf virus inoculum and viruliferous aphids for the states north of Kansas and probably did in 1959. In these states both winter and spring wheat is grown and the winter wheat is much later in maturity than in Kansas.

The winter barley varieties were so severely damaged by the cold weather and spring storms that this experiment must be repeated before evaluation of the varieties can be made. However, the plants that survived exhibited symptoms in all varieties and appeared to be susceptible.

R. padi proved to be an easy to handle, efficient vector in field experiments. The inoculation technique developed for large scale field use was highly effective. This was accomplished by rearing large quantities of viruliferous

aphids on flats of Renorbarley which were then taken to the field. Leaves with aphids were cut and placed along the crown of the plants and the aphids moved to the plants to be inoculated as the cut leaves began to dry. The aphids were active and transmission percentage was high.

Greenhouse testing of the varieties was ineffective. Differences apparent in the field could not be seen readily. Field testing has its difficulties, especially with the problem of maintaining virus free controls. But the field is the best place for final testing of possible resistance. Here the plants are subject to the extremes of the environment as is the virus and vector.

The testing of varieties should also include as many strains of the virus as possible before final classification is made. Breeding for resistance is feasible, and important as reported by other workers, and probably should be included in the Kansas breeding program.

ACKNOWLEDGMENTS

The writer expresses his appreciation for the guidance and suggestions of Dr. W. H. Sill Jr., major professor, during the course of this research project.

Thanks are also extended to Dr. S. M. Pady, Head, Department of Botany and Plant Pathology for the offer of the graduate research assistantship under which the study was conducted and to the rest of the committee; Dr. O. J. Dickerson and Dr. E. G. Heyne, for their assistance and contributions.

The writer's wife, Joyce, deserves much praise for her patience and encouragement while studying and particularly while preparing this thesis.

LITERATURE CITED

Allen, T. C., Jr. 1957. Strains of the barley yellow dwarf virus. Phytopathology 47:481-490.

Allen, T. C., Jr. and Byron R. Houston. 1956. Geographical distribution of the barley yellow dwarf virus. Plant Disease Reporter 40:21-25.

Arny, D. C. 1958. 1957 Barley Newsletter 1:76.

Barrus, M. F. 1937. Red leaf and blast of oats. Plant Disease Reporter 21:359-361.

Browning, J. A., J. C. Wheat, and K. J. Frey. 1959. Yellow dwarf of oats in Iowa in 1959. Plant Disease Reporter Supplement 262:336-342.

Bruehl, G. W., and H. V. Toko. 1955. A Washington strain of the cereal yellow dwarf virus. Plant Disease Reporter 39:547-549.

Bruehl, G. W., and H. V. Toko. 1957. Host range of two strains of the cereal yellow dwarf virus. Plant Disease Reporter 41:730-734.

Bruehl, G. W., and V. D. Damsteegt. 1959. Observations on cereal yellow dwarf of oats in Washington 1959. Plant Disease Reporter Supplement 262:369-371.

Bruehl, G. W. 1961. Barley yellow dwarf virus disease of cereals and grasses. American Phytopathology Society, Monograph Number I 52 p.

Caldwell, Ralph M., M. C. Wilson, and J. F. Schafer. 1959. Protection of oats against transmission of barley yellow dwarf through control of aphids with Dimethoate. Plant Disease Reporter Supplement 262:334-336.

Damsteegt, V. D., G. W. Bruehl, R. A. Nilan and C. Muir. 1961. Breeding for yellow dwarf resistance. 1960. Barley Newsletter 4:33.

Dickinson, E. A., W. B. Rayner and W. N. Foote. 1960. Insecticide treatments for aphid control in relation to spread of barley yellow dwarf virus. Plant Disease Reporter 44:501-504.

Dody, D.C. 1961. The transmission of the BYDV by the greenbug _Toxoptera graminum_ (Rondani). M. S. Thesis Kansas State University, Manhattan, Kansas. 36 p.

Endo, R. M., and C. M. Brown. 1957. Disease Resistance barley yellow dwarf virus. Agronomy Journal 49:503-507.

Endo, R. M. and C. N. Brown. 1963. Effects of barley yellow dwarf virus on yield of oats as influenced by variety, virus strain, and developmental stage of plants at inoculation. Phytopathology 53:965-968.

Galloway, B. T., and E. A. Southworth. 1890. Preliminary notes on a new and destructive oat disease. Journal of Mycology 6:72-73.

Jedlinski, H., and C. M. Brown. 1959. Barley yellow dwarf virus on oats in Illinois in 1959. Plant Disease Reporter Supplement 262:326-333.

Jedlinski, H. 1961. Problems and progress in evaluating spring and winter small grains and in particular oats for tolerance to barley yellow dwarf virus. Oat Newsletter 1961 page 33.

Manns, T. F. 1909. The blade blight of oats, a bacterial disease. Ohio Agriculture Experiment Station Bulletin 210:91-167.

Murphy, M. C. 1959. Introduction of the epidemic of barley yellow dwarf virus on oats in 1959. Plant Disease Reporter Supplement 262:316.

Oswald, J. W., and B. R. Houston. 1951. A new virus disease of cereals, transmissable by aphids. Plant Disease Raporter 35:371-475.

Oswald, J. W., and B. R. Houston. 1953. Yellow dwarf of cereals. California Agriculture 7:6-7.

Orlob, G. B., D. C. Arny and J. T. Medler. 1961. Aphid transmission of barley yellow dwarf virus in Wisconsin. Phytopathology 51:515-520.

Painter, R. H. 1951. Insect resistance in crop plants. Macmillan Company, New York. 520 p.

Palmer, Miriam A. 1952. Aphids of the Rocky Mountain region. Hirschfield Press, Denver, Colorado 452 p.

Patarson, J. L. 1963. Control of barley yellow dwarf in winter oats by a systemic insecticide. Plant Disease Reporter. 47:472-473.

Pizarro, A. C., and D. G. Arny. 1958. The persistence of systox in oat plants and its effect on the transmission of the barley yellow dwarf virus. Plant Disease Reporter 42:229-232.

Rasmusson, D. C., and C. W. Schaller. 1959. The inheritance of resistance in barley to yellow dwarf virus. Agronomy Journal 51:661-666.

Rochow, W. F. 1958. Barley yellow dwarf virus disease of oats in New York. Plant Diseasa Reporter 42:36-41.

Rochow, W. F. 1958. The role of aphids in vector specificity of barley yellow dwarf. Plant Disaasa Reportar 42:905-908.

Rochow, W. F. 1959. Diffarential transmission of virus from laaves singly and doubly infected by vector-specific strains of barley yellow dwarf virus. (Abstr.) Phytopathology 49:548.

Rochow, W. F. 1959. Transmission of barley yellow dwarf virus by two aphid species. Phytopathology 49:744-748.

Rochow, W.F. 1959, Differential transmission of barley yellow dwarf virus from fiald samples by four aphid species. Plant Disaase Reporter Supplement 262:356-360.

Rochow, W. F. 1960. The epidemic of barley yellow dwarf on oats in 1959. Cargill Crop Bulletin 35:1:16.

Rochow, W. F. 1960. Specialization among greenbugs in the transmission of barley yellow dwarf virus. Phytopathology 59:881-884

Rochow, W. F. 1960. Comparison of four aphid species as transmitters of barley yellow dwarf virus from oat field samples in New York. Plant Disease Reporter 44:940-942.

Rochow, W. F. 1960. Transmission of barley yellow dwarf virus acquired from liquid extracts by aphids feeding through membranes. Virology 12:223-232.

Rochow, W. F. 1965. Apparent loss of vector specificity following double infection by two strains of barley yellow dwarf virus. Phytopathology 55:62-68.

Russell, Louise M. 1963. Changes in the scientific names of some common aphids. U.S.D.A. Cooperative Economic Insect Report 13:84.

Saksena, K. N., D. G. Dody, and W. H. Sill Jr. 1964. Importance of the greenbug, Toxoptera graminum (Rhond.) in field transmission of barley yellow dwarf virus. Plant Disease Reporter 48:127-130.

Saksena, K. N., S. R. Singh, and W. H. Sill, Jr. 1964. Transmission of barley yellow dwarf virus by four biotypes of the corn leaf aphid. Rhopalosiphum madis (Fitch). Plant Disease Reporter 48:756-760.

Schaller, C. W. 1958. 1957 Barley Newsletter 1:29.

Schaller, C. W. 1960. A survey of the world barley collection for resistance to barley yellow dwarf virus. Phytopathology 50:653.

Schaller, C. W. 1961. 1960 Barley Newsletter 4:6.

Sechler, Dale T., J. M. Poehlman, M. D. Whitehead, and O. H. Calvert. 1959. The barley yellow dwarf virus-bacterial blight complex on oats in Missouri in 1959. Plant Disease Reporter Supplement 262:351-353.

Shands, H. L. and L. C. Cruger. 1959. Yield of certain oat varieties under natural epidemic conditions of yellow dwarf (Red Leaf) virus in Wisconsin. Plant Disease Reporter Supplement 262:371-374.

Sill, W. H. Jr., C. L. King, and E. G. Heyne. 1959. Barley yellow dwarf in Kansas oats and barley in 1959. Plant Disease Reporter Supplement 262:342-346.

Smith, H. C. and G. M. Wright. 1964. Barley yellow dwarf virus on wheat in New Zealand. New Zealand Wheat Review. 9:60-79.

Sprague, R. 1936. Leaf reddening in winter oats in western Oregon. Plant Disease Reporter 20:114-115.

Suneson, C. A. and R. T. Ramage. 1957. Studies on the importance of the yellow-dwarf virus. Agronomy Journal 49:365-367.

Takeshita, R. M. 1956. Strains of the yellow dwarf virus of cereals. (Abstr.) Phytopathology 46:28.

Takeshita, R. M. 1956. Identity of the oat red-leaf with the barley yellow dwarf virus. Phytopathology 46:436-440.

Timian, Roland G. 1964. Dodder transmission of barley yellow dwarf virus. Phytopathology (Abstract) 54:910.

Toko, H. V., and G. W. Bruehl. 1956. Apple grain and English grain aphids as vectors of Washington cereal yellow dwarf virus. Plant Disease Reporter 40:284-288.

Toko, Harvey V., and G. W. Bruehl. 1959. Some host and vector relationships of strains of the barley yellow dwarf virus. Phytopathology 49:343-347.

Watson, Marion A., and T. E. Mulligan. 1960. Comparison of two barley yellow dwarf viruses in glasshouse and field experiments. Annals of Applied Biology 48:559-574.

APPENDIX

Statistical Analysis

The chi-square 2x2 test was applied to test the hypothesis that the ratio of alive plants to total plants was the same in both the inoculated and control plots. The following table shows the adjusted chi-square value of wheat and winter barley varieties. A confidence interval of .90 at one degree of freedom gives the range of .00 to 3.84. Table 1.14.1, page 28 of George W. Snedecor's book: Statistical Methods (Fifth Edition) Iowa State University Press 1956 was used for a reference. The chi-square formula for testing the hypothesis of independence is found on page 221 of the same book.

Table 18. Test of independence for winter survival in treated and control plots of wheat and barley inoculated in the fall with BYDV.

Variety	a/ Adjusted Chi-square	Hypothesis
WHEAT		
Ottawa	0.085	Accept
Comanche	1.89	Accept
Kaw	2.11	Accept
Scout	5.52	Reject
RedChief	9.2	Reject
Wichita	11.4	Reject
Concho	11.8	Reject
Triumph	12.3	Reject
Bison	13.1	Reject
CI 13285	14.0	Reject
Pawnee	20.6	Reject
Ponca	31.5	Reject
BARLEY		
Reno	1.16	Accept
Hudson	14.0	Reject
Will	15.7	Reject
B-475	84.7	Reject
Chase	84.9	Reject
Dicktoo	114.9	Reject
Meimi	145.8	Reject

a/ C. I. .90 - .00 to 3.84 1965 yield data.

Table 17 shows there was not any effect upon the fall inoculation with BYDV on Ottawa, Comanche, Kaw, and Reno. All other varieties were effected by the inoculation and the winter kill per cent was increased.

The "t" distribution was applied to the yield data of the 1965 wheat, oats and spring barley varieties tested. None of the varieties were significant. The analysis was on a replication basis. The distribution of "t" was computed at 0.10 which is used for the confidence interval of 95 per cent. The table used for a reference is from Snedecor's book page 46 and the formula on page 91.

Table 19. Summaryof statistics for comparison of BYDV plots and healthy controls of wheat, spring barley and oats. Yield data compared per replication.

Variety		Calculated t	t at 0.10 CI .95	b/d. f.	Significant
SPRING BARLEY					
Beecher		0.0084	1.771	13	no
Otis		0.0144	1.771	13	no
OATS					
Tonka		0.0164	1.771	13	no
Andrew		0.02136	1.782	12	no
Kanota		0.0066	1.771	13	no
Mo-0-205		0.0121	1.771	13	no
Newton		0.0036	1.771	13	no
Minhafer		0.0086	1.782	12	no
Putnam		0.02882	1.782	12	no
Neal		0.02088	1.771	13	no
WHEAT					
CI 13285	Sa/	0.03408	1.833	9	no
	F	0.05083	1.895	7	no
Ottawa	S	0.0188	1.833	9	no
	F	0.08732	1.895	7	no
Ponca	S	0.01792	1.833	9	no
	F	0.0315	1.895	7	no
Bison	S	0.02448	1.833	9	no
	F	0.04879	1.895	7	no
Concho	S	0.02424	1.833	9	no
	F	0.03808	1.895	7	no
Pawnee	S	0.17160	1.833	9	no
	F	0.04186	1.895	7	no
RedChief	S	0.0353	1.833	9	no
	F	0.1374	1.895	7	no
Comanche	S	0.02389	1.833	9	no
	F	0.04035	1.895	7	no
Wichita	S	0.02794	1.833	9	no
	F	0.03022	1.895	7	no
Scout	S	0.01484	1.833	9	no
	F	0.0073	1.895	7	no
Kaw	S	0.02212	1.833	9	no
	F	0.0171	1.895	7	no
Triumph	S	0.0108	1.833	9	no
	F	0.03077	1.895	7	no

a/ S - spring inoculation, F - fall inoculation of BYDV.
b/ d.f. - degrees of freedom

EVALUATION OF SELECTED VARIETIES
OF WHEAT, BARLEY, AND OATS FOR
RESISTANCE TO BARLEY YELLOW DWARF VIRUS

By

LOUIS T. PALMER

B. S., Washington State University, Pullman, Washington, 1960

AN ABSTRACT OF A MASTER'S THESIS

Submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Plant Pathology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1965

Since the first reports of barley yellow dwarf virus (BYDV) in 1951, it has been recognized as a widespread and destructive disease of cereal crops throughout the world. There were several reports in the literature prior to 1951 describing a malady of oats, known as "Red Leaf of Oats", but the mode of disease transmission was not found until 1951. The epiphytotic of BYDV in the United States in 1959 caused severe losses to oats, barley and wheat. These losses were estimated at 35 million dollars or more. The Kansas oat crop alone suffered losses estimated at six and one half million bushels or 25 per cent of the crop.

Studies are in progress throughout the world to find varieties of oats, barley and wheat resistant to BYDV. This research was an attempt to evaluate the major varieties of cereal crops recommended in Kansas for possible resistance to BYDV.

Rhopalosiphum padi (Linnaeus), was found to be an efficient vector to use for BYDV transmission. Flats seeded with Reno barley were used to increase populations of viruliferous aphids for field inoculations.

In 1964 oats and barley were planted in four row blocks, ten feet long, randomized and replicated five times; four replications were BYDV tests and one was a control. In 1965 all varieties were randomized and replicated fifteen times, ten were test plots and five were control.

Six varieties of oats were tested in 1964 and eight varieties in 1965. Symptoms, stunting and some yield reduction, were observed in all varieties. Kanota seemed to be the most tolerant variety in 1964 while Newton and Minhafer were the most tolerant in 1965 when the weather was ideal for the oat crop. Environment plays an important part in the plant's response to the virus. In 1965 because of cool moist weather the spring oats displayed excellent growth despite infections of 70 per cent or more in the inoculated plots.

Two varieties of spring barley were tested in 1964 and 1965. Neither Beecher nor Otis had any degree of resistance, even with the ideal conditions for growth and high yields in 1965.

Seven varieties of winter barley were tested in 1965, but due to winter killing and storm damage in the spring, further study of these varieties is required before an evaluation can be made. Chase and Dicktoo survived better than Will, Reno, B-475 or Meimi. Hudson was nearly 100 per cent winter killed in the fall inoculation plots and more than 90 per cent in the control plots.

Twelve varieties of winter wheat were tested in 1965 and results indicate that fall inoculation of BYDV was much more severe than spring inoculation. Fall inoculation increased winter kill damage from one to twenty-two and yield reduction from twenty-six to sixty per cent. There was also more stunting observed in fall inoculation of BYDV.

An early spring inoculation reduced wheat yields more than a late inoculation. Two varieties, Triumph and Ponca, had a higher average per plant yield in the spring inoculation plots than in the controls. Comanche had a five per cent yield reduction and Kaw a thirty-five per cent in spring inoculation. Triumph was least damaged by fall inoculation with a twenty-six per cent yield reduction and Bison was the most with sixty per cent. Ottawa had the highest winter survival in the fall inoculation plots with only one per cent difference from the controls. The other wheat varieties tested were: Concho, RedChief, Scout, CI 13285, Wichita and Pawnee.

Of the four aphid species tested in fall and spring inoculations, R. padi was the most efficient vector. Schizaphis graminum (Rondani), R.maidis (Fitch), and Macrosiphum avenae (Fabricus), were not as efficient vectors for virus transmission in the field.

The presence of several strains of BYDV complicate the testing of varieties

for resistance and development of resistant varieties. It is known that at least two strains occur in Kansas and probably more. More information is needed on this subject.

Barley yellow dwarf virus is a serious disease of oats and barley in Kansas and could become a serious disease of wheat in a given year if conditions were favorable for aphid population build-up in the fall.

Although some varieties of wheat were seriously damaged by early spring infection it is unlikely that large vector populations will be present very often in Kansas in early spring to cause damage. The most serious probability is the increase of virus reservoirs and large aphid populations which could be a serious threat to the cereal crops grown in the states north of Kansas.